LIQUID RING PUMP

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application No. 60/440,892, filed January 17, 2003, where this provisional application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to pumps and compressors, and more particularly, to liquid ring pumps and compressors.

Background of the Invention

A liquid ring pump operates on the rotary liquid piston principle. A typical liquid ring pump A is shown in Figures 1 to 3. As shown in Figure 1, which is a schematic side view of liquid ring pump A, it consists of an annular housing 1, within which is eccentrically mounted a rotor 2 with radially extending and angularly spaced blades 3. During operation of liquid ring pump A, a working liquid introduced in housing 1 is forced outwardly by the rotating blades, thereby forming a liquid ring 4 concentric to housing 1. Gas is introduced in compression zones 5, which is defined as the spaces between blades 3, such space being closed off by the inner surface of liquid ring 4. Because of the eccentric position e(A) of rotor 2 and the concentric position c(A) of liquid ring 4, a piston action results as the position of liquid ring 4's inner surface in relation to rotor 2 varies depending on the compression zones' 5 circumferential location.

As shown in Figure 1, gas is introduced to compression zones 5 in a direction parallel to the axis of rotation e(A) of rotor 2 via a suction port 6 positioned at an axial end of liquid ring pump A. Similarly, gas is discharged from

compression zones 5 in a direction parallel to the axis of rotation of rotor 2 via a discharge port 7 positioned at an axial end of liquid ring pump A.

As shown in Figures 2 and 3, which are cut-out views of liquid ring pump A along lines 2-2 and 3-3 of Figure 1, respectively, a problem with liquid ring pump A's design is associated with the value of the clearance C_L which exists between housing 1's inner surface and the axial ends of blades 3. More specifically, as clearance C_L is lowered, friction between housing 1's inner surface and the axial ends of blades 3 increases, thereby having a negative impact on liquid ring pump A's efficiency. Conversely, as clearance C_L is increased, individual compression zones 5's integrity is compromised as gas can leak out of the axial ends of blades 3, thereby, again, having a negative impact on liquid ring pump A's efficiency. This limitation with liquid ring pump A's design results in tight tolerances having to be attained with respect to the value of clearance C_L, which has a negative impact on the costs of liquid ring pump A. Furthermore, liquid ring pump A's design is not amenable to having foreign substances being introduced in the compression zones 5. Indeed, dirt finding its way in compression zones 5 would likely also find its way to clearance C_L which, because of the small dimensions involved, would negatively impact liquid ring pump A's efficiency as friction forces would increase.

Accordingly, there is a general need for a liquid ring pump, which addresses the typical requirement of the need to have tight tolerances for the value of clearance C_L. There is also a need for a liquid ring pump that can better tolerate the introduction of foreign substances during operation without significant reduction in efficiency.

BRIEF SUMMARY OF THE INVENTION

The present invention is generally directed toward devices, systems and methods for use in compressing and/or pumping gases or vapors using a fluid ring pump. In one embodiment, a liquid ring pump is provided comprising a

housing and a rotor, the rotor being rotatably mounted eccentrically within the housing. The rotor comprises an annular inner surface having a plurality of radial apertures, a plurality of spaced blades interspersed between the plurality of radial apertures and at least a pair of side walls spaced apart axially along the annular inner surface with one side wall on each axial side of the radial apertures. The blades project radially outward from the annular inner surface. The side walls project outwardly from the annular inner surface and extending between the spaced blades to form a plurality of radially extending chambers. One blade may be positioned between each adjacent pairs of radial apertures. One side wall may be positioned on each side of the radial apertures. Gas enters and leaves the chambers through the radial apertures during operation.

The liquid ring pump may comprise port means for supplying gas to and receiving gas from the chambers through the apertures of the annular rotor.

The liquid ring pump may comprise an intake port positioned radially inward of the annular rotor for directing gas to the compression chambers and a discharge port positioned radially inward of the annular rotor surface for receiving gas discharged from the compression chambers, the discharge port being angularly spaced from the intake port.

The liquid ring pump may comprise means for routing the liquid from a first location within the housing, at which the liquid is subjected to a first pressure during operation, to a contact surface between moving parts of the liquid ring pump, the contact surface being at a second location at a second pressure less than the first pressure during operation.

The liquid ring pump may comprise an aperture positioned on an outer surface of a contact journal of the liquid ring pump and a channel positioned radially inward of the contact journal for providing liquid to the aperture. The liquid ring pump may further comprise a connection between the housing and the channel for providing liquid in the liquid ring to the contact journal during operation.

The housing may be configured to rotate about an axis parallel to an axis of the rotor, the housing having a plurality of inwardly extending elements adapted to cause the liquid in the liquid ring pump to rotate when the rotatable ring is rotated. Alternatively, the housing may comprise a rotatable ring configured to rotate about an axis parallel to an axis of the rotor, the rotatable ring having a plurality of inwardly extending elements adapted to cause the liquid in the liquid ring pump to rotate when the rotatable ring is rotated. Alternatively, the housing may comprise a rotatable ring configured to rotate about an axis parallel to an axis of the rotor, the rotatable ring having means to cause the liquid in the liquid ring pump to rotate when the rotatable ring is rotated. The liquid ring pump may further comprise an actuator, the actuator being magnetically couplable to the rotatable ring to controllably rotate the liquid.

In another embodiment, a rotor is provided for being rotatably mounted eccentrically within a housing on a liquid ring pump. The rotor comprises an annular inner surface having a plurality of radial apertures, a plurality of spaced blades interspersed between the plurality of radial apertures and at least a pair of side walls spaced apart axially along the annular inner surface with one side wall on each axial side of the radial apertures. The blades project radially outward from the annular inner surface. The side walls project outwardly from the annular inner surface and extend between the spaced blades to form a plurality of radially extending chambers.

In another embodiment, a rotor is provided for being rotatably mounted eccentrically within a housing on a liquid ring pump. The rotor comprises an annular inner surface having a plurality of radial apertures and a plurality of walled cells. The walled cells project radially outward from the annular inner surface. A wall on each of the walled cells extend around at least one of the radial apertures.

In another embodiment, a liquid pump is provided comprising a housing. The housing has a rotatable ring configured to rotate about a rotary axis.

The rotatable ring has a plurality of inwardly extending elements adapted to cause a liquid in the liquid ring pump to rotate when the rotatable ring is rotated. The liquid ring pump further comprises a rotor. The rotor is mounted within the housing to rotate at least partially within the rotatable ring about an axis parallel with the rotary axis. The rotor is eccentrically positioned within the housing. The rotor comprises an annular inner surface having a plurality of radial apertures, a plurality of spaced blades interspersed between the plurality of radial apertures and at least a pair of side walls spaced apart axially along the annular inner surface with one side wall on each axial side of the radial apertures. The blades project radially outward from the annular inner surface. The side walls project outwardly from the annular inner surface and extend between the spaced blades to form a plurality of radially extending chambers. The liquid ring pump further comprises an actuator. The actuator is magnetically couplable to the rotatable ring to controllably rotate the liquid.

In another embodiment, a liquid ring pump is provided comprising a housing, a rotor and means for routing the liquid from a first location within the housing to a contact surface between two moving parts of the liquid ring pump. The first location is at a first pressure during operation. The contact surface is at a second pressure during operation, the second pressure being less than the first pressure. The rotor is rotatably mounted eccentrically within the housing and is configured to cause the liquid to rotate within the housing during operation.

The housing may comprise a rotatable ring configured to rotate about an axis parallel to an axis of the rotor. The rotatable ring comprises means to cause the liquid in the liquid ring pump to rotate when the rotatable ring is rotated.

The liquid ring pump may comprise an actuator. The actuator is magnetically couplable to the rotatable ring to controllably rotate the liquid.

In another embodiment, a method for operating a liquid ring pump is provided. The method comprises rotating a rotor, the rotor being eccentrically mounted within a housing to cause the liquid to flow circumferentially around an

interior of the housing. The method further comprises directing a portion of the liquid from an area within the housing subject to a relatively high pressure to an area within the housing subject to a relatively low pressure. As a result, liquid flows between at least two adjacent parts to facilitate relative movement between the two parts.

Many specific details of certain embodiments of the invention are set forth in the detailed description below to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, or may be practiced without several of the details described.

BRIEF DESCRIPTION OF THE DRAWINGS)

Figure 1 is a schematic side view of a liquid ring pump according to the prior art.

Figure 2 is a schematic cross-sectional view of the liquid ring pump of Figure 1, viewed along Section 2-2.

Figure 3 is a schematic cross-sectional view of the liquid ring pump of Figure 1, viewed along Section 3-3.

Figure 4 is an exploded isometric view of a liquid ring pump according to an embodiment of the present invention.

Figure 5 is a partial diametric cross-section of the liquid ring pump of Figure 4.

Figure 6 are views of the housing of the liquid ring pump of Figure 4.

Figure 7 is an exploded isometric view of the rotor of the liquid ring pump of Figure 4, shown with some of the elements diametrically cross-sectioned for clarity.

Figures 8A and 8B are isometric views of the rotor of the liquid ring pump of Figure 4.

Figure 9 is an exploded isometric view of a liquid ring pump according to another embodiment of the present invention.

Figure 10 is a partial diametric cross-section of the liquid ring pump of Figure 9.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Many specific details of certain embodiments of the invention are set forth in the detailed description below, and illustrated in enclosed Figures 4-10, to provide a thorough understanding of such embodiments. One skilled in the art, however, will understand that the present invention may have additional embodiments, or may be practiced without several of the details described.

Figures 4 and 5 illustrate a liquid ring pump 10 according to one embodiment of the present invention. Liquid ring pump 10 generally incorporates a housing 12A and 12B (also shown in Figure 6), an annular rotor 14 (also shown in Figure 7) and an intake-discharge port assembly 16 (also shown in Figures 8A and 8B).

In the current embodiment, housing 12A/12B is a 2-part element which, when connected to one another, forms an inner annular surface 18. Rotor 14 is mounted eccentrically within housing 12A/12B, *i.e.*, axis of rotation e(B) of rotor 14 does not align with geometric center axis c(B) of housing 12A/12B. Consequently, as best illustrated in Figure 5, the distance between rotor 14 and inner annular surface 18 of housing 12 varies angularly about the perimeter of the rotor.

Rotor 14 comprises a plurality of radially extending and angularly spaced blades 20 (Figure 7) and sidewalls 22 (Figure 7), configured to form radially extending and outwardly opened compression zones 24 spaced about the perimeter of the rotor. In the illustrated embodiment, each compression zone 24 is completely surrounded by a pair of opposing blades 20 and a pair of opposing sidewalls 22. The outermost portion of each of compression zones 24, also

referred to as the outward opening, is open to the outside. The inventors appreciate that more or fewer blades 20 and/or sidewalls 22 can be spaced radially and axially about the rotor.

During operation, the outward openings of compression zones 24 are closed-off by a liquid ring, which is rotated within housing 12 by the corresponding rotation of rotor 14. The inward portion of each of compression zones 24 is closed off but for an aperture 25 in each of compression zones 24 that enables gas or vapor to pass from/to port assembly 16 to/from the relevant compression zone 24. As rotor 14 rotates and the liquid ring moves radially outward and inward with respect to compression zones 24, the gas or vapor is drawn in or discharged out of the compression zone, respectively.

Rotor 14 is positioned concentrically outside of port assembly 16, and the rotor rotates around the port assembly, which is secured to the inner end of housing 12B via a couple of screws protruding through orifices 13 (Figure 6). Port assembly 16 includes an intake port 26 and a discharge port 28 (Figure 8A), both of which are aligned axially with apertures 25 on rotor 14 during use, so that gas or vapor passing through the aperture will also pass through the respective port when the two are aligned with each other.

Intake port 26 is routed to direct gas or vapor from a gas or vapor source through an intake opening 26A (Figure 6) in housing 12B to compression zones 24 via apertures 25 as the respective apertures/compression zones rotate past intake port 26. Similarly, discharge port 28 directs gas away from compression zones 24 via apertures 25 through a discharge opening 28A (Figure 6) in housing 12B to a storage device or other user as the respective apertures/compression zones rotate past discharge port 28. Intake port 26 is positioned angularly within housing 12 to correspond to a location at which the liquid ring is moving outward with respect to compression zone 24. Consequently, when the respective aperture 25 aligns with intake port 26, a negative pressure in compression zone 24 draws gas or vapor from a gas or vapor source into the

compression zone. Likewise, discharge port 28 is positioned to correspond to a location at which the liquid ring is moving inward with respect to compression zone 24, such that a positive pressure in the compression zone forces gas or vapor out of the compression zone. The inventors appreciate that the exact angular locations of the ports can be varied to optimize the transfer of gas or vapor between ports 26/28 and compression zones 24.

The water necessary for the formation of the liquid ring can be introduced to liquid ring pump 10 through intake opening 26A, either by adding it to gas or vapor being directed to liquid ring pump 10 or extracting it from such gas or vapor.

As shown in Figure 4, rotor 14 is driven within housing 12A/12B by an electric motor, which incorporates windings 32 and magnets 34. Windings 32 are fixed to housing 12A, and magnets 34 rotate within windings 32. Magnets 34 are coupled to an elongated neck 38 of rotor 14, which can be fixed so that magnets 34, rotor 14 and elongated neck 38 rotate as a unit within housing 12A/12B. In the illustrated embodiment of Figure 7, magnets 34 are pressure fit onto an enlarged distal portion 39 of neck 38. The inventors appreciate that the magnets 34 can be attached to the rotor 14 by other means known in the art. Windings 32 are held in position via end cap 52, which in turn is secured to housing end 12A.

Elongated neck 38 of rotor 14 is hollow, so as to slideably fit over column 40 which extends from port assembly 16. In the current embodiment, such fit is accomplished via first contact bearing 36 (best shown in Figure 7), positioned on the inner surface of hollow elongated neck 38, and first contact journal 41 (best shown in Figure 8B), positioned on the outer surface of column 40. First contact bearing 36 and first contact journal 41 are adapted to reduce the friction between each other.

As shown in Figure 4, a slotted second contact bearing 44 is positioned on the inner surface of compression zones 24 of rotor 14. Slots, or in

the illustrated embodiment, holes 46 are spaced around the perimeter of slotted second contact bearing 44 and are positioned axially to align with apertures 25 in rotor 14 to allow gas or vapor to pass through. Slotted second contact bearing 44 rotates with rotor 14 as a unit and slideably fits over the outer surface of port assembly 16 which, in the current embodiment, is encircled by a slotted second contact journal 17 (best shown in Figure 8A) with slots positioned to align with intake port 26 and discharge port 28. Second contact bearing 44 and second contact journal 17 are adapted to reduce the friction between each other. Rotor 14 is held in place over port assembly 16 via a pressure plate 48 and a removable screw 49 received within opening 42 at extremity of column 40. A pair of thrust bearings 50/51 are positioned on opposing ends of neck 38 to reduce friction between rotor 14 and port assembly 16/column 40. During operation of liquid ring pump 10, there are typically no appreciable loads on thrust bearings 50/51 as windings 32/magnets 34 assembly are adapted to properly position axially rotor 14 over port assembly 16/column 40.

As stated above, first contact bearing 36 and first contact journal 41, as well as second contact bearing 44 and second contact journal 17, are adapted to reduce the friction between each other. In the current embodiment, this is accomplished by the introduction of water bleed holes 60 and 61 in port assembly 16/column 40. Such bleed holes (60-61) link the outer surface of first contact journal 41 and second contact journal 17 to a channel 65 (Figure 5) positioned in port assembly 16/column 40. Water introduced to channel 65 via water bleed intake port 66 migrates to the outer surface of first and second contact journals (41 & 17 respectively) so that a thin water film is created between such journals and first and second contact bearings 36 and 44. In the current embodiment, the water introduced to bleed intake port 66 originates from the circumferentially outward portion of the liquid ring via a bleed line 68 (Figure 4) linking bleed intake port 66 to a bleed discharge port 70 (Figure 4) positioned in housing 12B: because of the pressure gradient between bleed discharge port 70 and bleed intake port 66 during

operation, water naturally migrates to channel 65, thereby ensuring a constant supply of water for the water film created between first and second contact bearings (36 and 44) and first and second contact journals (41 & 17).

Figures 9 and 10 illustrate a liquid ring pump 110 according to an alternate embodiment of the present invention. Similar to the previous embodiment, pump 110 incorporates a housing 112 [a 2-part element (112A-112B) which, when connected to one another, forms an inner annular surface] and a rotor 114 which rotates around an intake-discharge port assembly 116. Similar to the previous embodiment, rotor 114 has a number of compression zones 124, made up of blades 120 and sidewalls 122, and each having at least one aperture 125 at its inward end, as with the previous embodiment. In this embodiment, however, rotor 114 is not driven by a drive shaft but rotates freely around port assembly 116. As rotor 114 rotates in a rotating ring of liquid, the intake and discharge of gas or vapor operates similar to that described above through intake port 126 and discharge port 128.

Rotor 114 and the ring of liquid are driven in this embodiment without a drive shaft. Instead, housing 112, more specifically in this embodiment bottom-housing element 112A, incorporates an electric motor rotor. An external stator 132 drives the electric motor rotor of housing 112, so that it drives housing 112. Because stator 132 is fixed in relation to port assembly 116, stator 132 drives housing 112 to rotate around port assembly 116. The internal surface of housing 112 has a number of fins 135 projecting inward. Rotation of housing 112 thus results in rotation of the liquid. Rotation of the liquid in turn results in rotation of rotor 114. Rotor 114 is thus rotated in housing 112 without a shaft, which translates to a significant reduction in the numbers of seals and bearings incorporated in pump 110. With fewer seals and bearings, pump 110 of the present invention may require less maintenance, fewer replacement parts, and consequently may have an extended useful life as compared to pumps of the prior art.

The inventors appreciate that other embodiments of the internal surface of housing 112 are possible to induce rotation of the liquid: instead of a number of fins 135 projecting inward from the internal surface of housing 112, said surface may comprise any type of protrusions that will induce rotation of the liquid; said surface may alternatively have a high coefficient of friction with the liquid so that rotation of the liquid will be induced.

The inventors also appreciate that, instead of housing 112 rotating around port assembly 116, an element positioned within the housing, such as a rotatable ring or sleeve, magnetically coupled to stator 132, may alternatively drive the rotation of the liquid.

Similar to the previous embodiment, the introduction of water bleed holes can be used to effectively reduce friction between the moving parts. In this embodiment, this is accomplished as follows. The axis of rotation of rotor 114 in this embodiment is vertical, with bottom-housing element 112A, which encloses port assembly 116 and rotor 114, being positioned at the vertically lowest portion of pump 110. Consequently, being naturally drawn to bottom-housing element 112A, the liquid serves to constantly lubricate the surfaces between port assembly 116 and rotor 114, reducing or eliminating the need to lubricate, oil or grease pump 110. The system can be further adapted with a fluid circulation system that draws liquid from bottom-housing element 112A and injects it between the moving parts to further lubricate the system, similar to that discussed above.

This embodiment also reduces or eliminates the need for seals. In the current embodiment, bottom-housing element 112A is cup shaped, with top housing element 112B being attached to its open end. Top housing element 112B closes off open end of bottom-housing element 112A and wraps around the protruding end of port assembly 116. The top end of top housing element 112B comprises an inner lip 170 to catch any of the liquid leaking out of pump 110. Such liquid can then be redirected to pump 110 through, for example, bleed hole

160 linking the top surface of the protruding end of port assembly 116 to the outer surface of such protruding end.

The inventors appreciate that the axis of rotation of rotor 114 may be other than vertical and that such a feature would necessitate modifications that would be well known by those skilled in the art, such as the introduction of a sealing mechanism at the protruding end of port assembly 116, as lip 170 would likely not be sufficient.

While particular elements, embodiments and applications of the present method and apparatus have been shown and described herein, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. It is therefore contemplated by the appended claims to cover such modifications as incorporate those features that come within the scope of the invention.